CHAPTER 8

ENVIRONMENTAL BENEFITS OF FINAL REGULATION

8.1 INTRODUCTION

The final effluent limitations guidelines for concentrated aquatic animal production (CAAP) facilities requires permittees subject to the final rule to establish practices to control solids (e.g., employ efficient feed management and feeding strategies to minimize potential discharges of uneaten feed and waste products to waters of the U.S.), properly store drugs, pesticides, and feed; regularly maintain, routinely inspect and promptly repair any damage to the production system and wastewater treatment system; maintain certain records and provide for employee training. In addition, the final regulation establishes certain reporting requirements relating to the use of investigational new animal drugs (INADs) or approved drugs used in an extralabel fashion and relating to failure in or damage to the structure of an aquatic animal containment system. Please see the final regulatory text, as well as Chapter 4 of this document, for specifics on final regulatory requirements. These requirements, according to EPA loadings estimates, will reduce facility discharges of TSS and pollutants associated with the reduction in TSS discharges including total nitrogen (TN), total phosphorus (TP), and biochemical oxygen demand (BOD). EPA has also found that reductions in TSS will lead to reductions for feed contaminants (e.g., metals) as a result of these final requirements. Pollutant load estimates are discussed in Chapter 10 of USEPA (2004).

Reductions in these loadings (TSS, TN, TP, BOD, metals, and feed contaminants) could affect water quality, the uses supported by varying levels of water quality, and other aquatic environmental variables (e.g., primary production and populations or assemblages of native organisms in the receiving waters of regulated facilities). These impacts may result in environmental benefits, some of which have quantifiable, monetizable value to society. For the final regulation, EPA has only monetized benefits from recreational and non-use benefits associated with water quality improvements from reductions in TSS, TN, TP, and BOD (Table 8-1 provides a summary of the environmental benefits of the final regulation). EPA did not attempt to estimate benefits from possible reductions of feed contaminants discharged to receiving waters that may arise from reporting requirements. EPA anticipates that other requirements of the final rule will benefit the environment. For example, EPA believes that the requirement to notify the permitting authority of the use of INADs and approved drugs used in an extralabel fashion is necessary to ensure that any potential risk to the environment resulting from the use of these drugs can be addressed with site-specific remedies where authorized. This provides the permitting authority with the opportunity to monitor or control the discharge of the drugs while the drugs are being applied. EPA also anticipates that requirements relating to structural integrity of production and wastewater treatment system will also result in reduced losses of material to waters of the U.S. However, EPA has not attempted to monetize these anticipated benefits. This chapter will present a summary of results and the methods EPA used to evaluate only the potential monetized environmental benefits of the regulation.

Table 8-1
Summary of Environmental Benefits of the Final Rule

Type of Benefit	Environmental Benefits (Thousands of $2003)
Recreational and non-use benefits from improved water quality resulting from final requirements to establish solids control and feed management practices	Option A: $84 Option B: $94 - $118 FINAL OPTION: $66 - $99
Reduced discharge of feed additives/contaminants (e.g, metals, PCBs, other trace substances) from final requirements to establish solids control and feed management practices	not monetized
Better opportunity for permitting authority to evaluate potential for environmental risk and establish site-specific remedies, as appropriate, from required reporting to permitting authority of certain drug uses as described in rule	not monetized
Improved containment of materials and response to containment system damage or failure resulting from final reporting requirements regarding damage/failure of containment system and final requirements regarding maintenance practices	not monetized
Requirements for practices regarding proper materials (drugs, pesticides, and feed) storage and management of spilled materials	not monetized

8.2 MONETIZED BENEFITS

8.2.1 Overview of Method

EPA monetized water quality benefits resulting from the final rule using a combination of engineering, scientific, and economic analyses. EPA used engineering analyses to estimate reductions in TSS, nitrogen, phosphorus, and BOD loads from affected facilities under the final regulation (Table 10.6-2 and Chapter 10 of the TDD), water quality modeling tools to simulate the effects of these loading reductions on the water quality of receiving waters to which regulated facilities discharge, and economic valuation tools to estimate the monetary value that society places on these changes in water quality. Instead of assessing water quality impacts for each individual facility in the regulated population, EPA developed a set of water quality modeling "case studies" that were used to represent groups of facilities in the regulated population. EPA assumed that facilities in each group would experience water quality responses to the final regulation similar to those of the representative case study, and used these estimated water quality responses as the basis for estimating monetized benefits at regulated facilities.

EPA used facility-specific data (from the detailed industry questionnaire, see following section) for use in estimating and monetizing national environmental benefits[7]. The detailed questionnaire data provided specific information about each facility, such as facility configuration, feeding rates, system flows, and facility location. Some of this information was used in the engineering analysis to provide pollutant loading estimates under baseline and different regulatory option scenarios. These pollutant load estimates were used with the flow data in the QUAL2E modeling. Facility location information was used to determine the relationship of the facility effluent to the receiving water and to evaluate geographic relationships among facilities.

The following sections describe data sources, procedure for estimating national benefits based on results for a subset of facilities, and EPA's application of the water quality and economic valuation tools to estimate national environmental benefits from the final regulatory requirements for TSS.

8.2.2 Detailed Questionnaire Data

As described in the Notice of Data Availability for the CAAP rule (68 FR 75072, December 29, 2003), EPA developed a detailed questionnaire to collect data from CAAP facilities as the basis for estimating costs and benefits of the final CAAP rule. The detailed questionnaire itself, EPA's intended use of the data, sampling design, summary of responses received, and other aspects of the detailed questionnaire are all available in the administrative record for the final CAAP rule (USEPA, 2002; USEPA, 2004). Briefly, EPA mailed detailed questionnaires to a stratified random sample of aquaculture facilities. Of these, a large proportion of questionnaires were completed, returned to EPA, and were able to be used in subsequent analyses. Because EPA selected these facilities using a statistical design (see Appendix A of the Technical Development Document for the proposed rule), the responses allowed EPA to build a database to use for estimating population characteristics. That is, EPA had classified aquaculture facilities into strata defined by facility type (commercial, government, research, or tribal), the predominant species, and predominant production, and a sample was drawn from the population of aquaculture facilities ensuring sufficient representation of facilities in each of the strata. For national (i.e., population) estimates, EPA applied survey weights to the facility responses that incorporate the statistical probability of a particular facility being selected to receive the detailed questionnaire and adjust for non-responses. In this case, a survey weight of "3" means that the facility represents itself and two others in the population. As with cost and loading analyses for the final rule, EPA uses the detailed questionnaire database and sample weights as the basis for analysis of the environmental benefits of the regulation. In the subsequent discussions in this Chapter, a "detailed questionnaire facility" refers to a facility which completed and returned a detailed questionnaire which was able to be used in EPA's analyses.

---

[7]This approach extends the approach used in the environmental benefits analysis for the proposed rule by configuring water quality models to better represent the varying characteristics of CAAP facilities in the scope of the final regulation. For the proposed rule, EPA estimated water quality-related benefits for flow-through and recirculating facilities by simulating the water quality impacts of varying "model" facility discharge scenarios on a single "prototype" stream reach. EPA used the results of these scenarios to estimate national environmental benefits (see the proposal EA for additional details). EPA's current modeling approach used estimates for facility-specific effluent concentrations and flow rates to more accurately represent the contribution of individual facilities to receiving water changes. The revised approach also used receiving stream characteristics that represent background water quality conditions and hydraulic properties of receiving waters to which CAAP facilities discharge.

8.2.3 Extrapolation Framework

EPA developed a method to guide selection and development of a limited number of water quality modeling case studies that would be representative of the facilities for which EPA received a usable detailed questionnaire and that were in the scope of the final regulation. First, EPA assumed that water quality improvements at regulated facilities will be driven by three factors: the relative change in pollutant loadings resulting from the regulation, the concentration of the pollutants in the discharge, and the amount of dilution that occurs when the discharge enters the receiving water[8]. EPA then assigned each detailed questionnaire facility in the scope of the final regulation with non-zero load reductions into one of eight possible subgroups ("extrapolation categories") based on their value ("Low" or "High") for each of these three factors. EPA determined each facility's value for each factor as follows:

8.2.3.1 Factor 1: Regulatory Changes in Pollutant Loadings

EPA assumed that the percentage of pollutant load reductions at a given facility under the final rule would be one important factor in determining the magnitude of water quality response to the regulation. Water bodies receiving discharge from facilities that experience a large percentage reduction in pollutant loads as a result of the final regulation have the potential to experience larger water quality responses than those receiving discharge from facilities that experience smaller load reductions. EPA estimated percent TSS load reductions for each facility based on data provided by facilities in the detailed questionnaires, and with supplemental engineering analysis of the facility-provided data, where necessary. Percent load reductions for in-scope, detailed questionnaire facilities ranged from less than 1% to greater than 50%. A full description of load estimate calculations is provided in Chapter 10 of the Technical Development Document. The median percent TSS load reductions value for the detailed questionnaire facilities[9] was used as the threshold between the "Low" and "High" categories for this factor.

8.2.3.2 Factor 2: Pollutant Concentration in Discharge

EPA assumed that the baseline TSS concentrations of pollutants in facility effluents discharged to receiving waters would be a second important factor in determining the magnitude of water quality response to the regulation. EPA assumed that if baseline TSS concentrations of pollutants were low, then water quality responses to reductions in pollutant concentrations would be limited; conversely, if baseline TSS concentrations of pollutants were high, then water quality responses to reductions had the potential to be larger. EPA assessed baseline TSS concentrations in flow-through and recirculating system

[8]EPA informally evaluated the relationship between the three factors - % TSS load reduction, baseline TSS concentration, and dilution ratio - and water quality response by analyzing the relationship between these three factors and an output from a set of water quality modeling simulations. EPA performed multiple regression analyses between the three explanatory factors and an aggregate measure of water quality response (change in WQI6, a metric described later in this document) using four different model specifications. Using a linear model specification, the three explanatory factors explained 89% of the variation; using a log-log specification, the three explanatory factors explained 99% of the variation in d(WQI6). See McGuire (2004c).

[9]Median value estimate for percent TSS load reduction from median value indicated on April 2, 2004 Tetra Tech spreadsheet (Tetra Tech, 2004).

facilities that provided detailed production, feeding, facility configuration, and flow rate data. Baseline effluent TSS concentrations for in-scope, detailed questionnaire facilities ranged from less than 1 mg/L to greater than 40 mg/L. A more detailed explanation is available in Chapter 10 of the Technical Development Document. Again, EPA used the median baseline TSS concentration as the threshold between the “Low” and “High” extrapolation categories[10].

8.2.3.3 Factor 3: Dilution of Discharge in Receiving Water

EPA assumed that the amount of dilution that occurs in the receiving waters to which a facility discharges would be a third important factor determining the magnitude of water quality response to the regulation. Dilution ratios were estimated by dividing the facility flow by the sum of the receiving water flow and the facility flow. If the effluent flow rate is small relative to receiving water flow (low dilution ratio), then water quality response to the regulation is likely to be smaller than if the effluent flow rate is large relative to receiving water flow rate. EPA obtained effluent flow rates from data provided by facilities in the detailed questionnaires. EPA obtained receiving water flow data from a database of estimated mean annual and summer flows for all streams in the “Reach File 3" national stream reach network (USEPA, 2003; McGuire, 2004b). Due to limitations in the quality of geographic referencing data available (e.g., latitude and longitude coordinates whose accuracy could not be established) and other data limitations, EPA was able to estimate receiving water flow rates and dilution ratios at a subset of detailed questionnaire facilities. Dilution factors ranged from less than 0.01 to 0.90 for in-scope, detailed questionnaire facilities for which dilution ratios could be determined. Again, EPA used the median value as the threshold between the “Low” and “High” extrapolation categories for this factor[11].

Eight distinct “extrapolation categories” can be generated based on different combinations of the above three factor values. For example, a category defined by “Low” percent TSS load reduction, “Low” baseline TSS concentration, and “Low” dilution ratio is designated “LLL;” similarly, the categories “LLH”, “LHL,” “LHH,” “HLL,” “HLH,” “HHL,” “HHH” can be defined (Table 8-2). Using the thresholds described above and the detailed questionnaire data, EPA assigned each in-scope, detailed questionnaire facility with non-zero load reductions under Option B to an appropriate extrapolation category (Table 8-2). For similar information for Option A and the final Option, see McGuire 2004a.

Furthermore, EPA assumed that a facility’s water quality response to the regulation would be similar to other facilities in the same extrapolation category, and therefore developed case studies for key categories. Additionally, EPA assumed that each in-scope facility from the detailed survey sample represents a specific number of facilities in the total population of in-scope facilities, and that the specific number of in-scope facilities from the total population can be adequately represented by the detailed survey facility’s sample weight. Table 8-2 also shows national estimates for the number of in-scope facilities for each extrapolation category. The 24 in-scope detailed questionnaire facilities that have load reductions (and for which EPA has detailed survey data) nationally represent 86 facilities with load reductions. There were 9 detailed questionnaire facilities (when multiplied by sample weights, this equals

---

[10]Median value estimate for baseline TSS concentration from median value indicated on April 2, 2004 Tetra Tech spreadsheet (Tetra Tech, 2004).

[11]Median value estimate for dilution ratio from median value indicated on April 2, 2004 Tetra Tech spreadsheet (Tetra Tech, 2004).

approximately 27 facilities in the national population of facilities affected by the final regulation) that could not be accurately categorized because of missing receiving-water flow data.

Table 8-2
Definition of Extrapolation Categories* and National Estimates for the Number of Facilities In-scope for the Regulation—Option B Only

(A) Extrapolation Category	(B) Extrapolation Category Label	(C) Number of In-Scope Detailed Questionnaire Facilities	(D) National Number of In-scope Facilities
% TSS load reduction low = L Baseline TSS concentration low = L Dilution ratio low = L	LLL	2	7
% TSS load reduction low = L Baseline TSS concentration low = L Dilution ratio high = H	LLH	3	11
% TSS load reduction low = L Baseline TSS concentration high = H Dilution ratio low = L	LHL	1	4
% TSS load reduction low = L Baseline TSS concentration high = H Dilution ratio high = H	LHH	4	18
% TSS load reduction high = H Baseline TSS concentration low = L Dilution ratio low = L	HLL	0	0
% TSS load reduction high = H Baseline TSS concentration low = L Dilution ratio high = H	HLH	1	4
% TSS load reduction high = H Baseline TSS concentration high = H Dilution ratio low = L	HHL	2	7
% TSS load reduction high = H Baseline TSS concentration high = H Dilution ratio high = H	HHH	2	8
Missing receiving water flow data	n/a	9	27
Total	n/a	24	86

NOTE: All facilities represented in this Table are estimated to have non-zero load reductions under the Option B. For similar information for Option A and the final Option, see McGuire 2004a.
* See text for an explanation of extrapolation categories. Values in Column (D) are rounded; they are obtained by summing the sample weights associated with all facilities represented in Column (C).

8.2.4 Water Quality Modeling

8.2.4.1 Selection and Development of Case Studies

Resource and data limitations constrained the number of QUAL2E applications that could be performed. EPA developed QUAL2E models for one representative "case study" facility for the following extrapolation categories: LHL, LHH, HLH, and HHL. QUAL2E simulations were also performed for the HHH extrapolation category, using QUAL2E models already developed for the LHH category. A more detailed discussion of this process is discussed below. Case studies were not performed for the LLL, LLH, and HLL categories because (a) no facilities were in the HLL category and (b) EPA focused modeling resources on categories expected to represent a larger proportion of benefits. Water quality improvements for facilities in the LLL and LLH categories were expected to be smaller than improvements for facilities in the other categories.

Since in-scope CAAP facilities are located throughout the United States, EPA considered CAAP facilities throughout the country when choosing representative "case studies." Water quality models were developed and configured for existing, monitored facilities. Each case study model was configured with receiving stream characteristics to represent geographically similar conditions at the existing facility.

EPA's selection process of these case study sites also considered the following information:

- Availability of physical data from similar local streams for configuration of model inputs
- Availability of stream water quality data for developing upstream and downstream conditions
- Amount of data available for CAAP facility effluent flows (water quality and magnitude of flows) to accurately characterize stream inputs from the facility
- Type of CAAP facility production system and species

Availability of data for model configuration and calibration[12] was a key consideration for study site selection. Locations of water quality and streamflow monitoring stations around existing facilities were obtained from the EPA's BASINS and STORET databases and USGS. In addition, BASINS datasets were utilized for identification of environmental and spatial features of the receiving stream. The final selection of sites for developing water quality models represented a balance between available resources, the accessibility of the suitable data, and the number of facilities that could be represented with a specific site.

For each selected study site, background information was collected regarding characteristics of the watershed, stream, and CAAP facility. This information included analyses of the physical extent of the watershed to the point of the CAAP facility's discharge, land use within the watershed that are potential nonpoint sources of pollution to the stream, proximity of other dischargers that could potentially influence analysis of the isolated impact of the CAAP facility, and other environmental or meteorological attributes of the region that distinguish the study site. Additional information about how the specific sites were selected is available (Hochheimer, 2004).

[12] EPA performed calibration adjustments to many of the QUAL2E model input variables during the modeling process. See the model reports (Hochheimer et al., 2004 a-d) for more information on model parameterization.

Special attention was placed on selection of appropriate study sites to ensure that hydraulic/hydrologic and loading processes were not present that would affect model configuration and calibration, and analysis of model results. An ideal study site will attempt to isolate the impacts of a CAAP facility so that modeling analysis will not be impaired by unforeseen influences not simulated by the model.

8.2.4.2 Model Configuration

The selected model for analysis of CAAP facility impacts during proposal was a steady state application of QUAL2E (Brown and Barnwell, 1987). EPA extended this application to model CAAP facilities using QUAL2E during critical design conditions (e.g., low flow, high temperatures) at specific facilities that provided information in the detailed survey. QUAL2E is capable of simulating up to 15 water quality constituents, including:

- Dissolved oxygen
- Biochemical oxygen demand
- Temperature
- Chlorophyll a
- Organic nitrogen
- Ammonia
- Nitrite
- Nitrate
- Organic phosphorus
- Dissolved phosphorus
- Coliforms
- An arbitrary nonconservative constituent
- 3 conservative constituents

Relative to other models currently available, QUAL2E was selected as the ideal tool for impact analysis due to input data requirements and parameters modeled. QUAL2E provided EPA with the ability to simulate several constituents using model processes that can be logically parameterized and justified using assumptions based on either collected data or literature. Moreover, the detail of the processes modeled by QUAL2E provided EPA with a good balance between available data, assumptions required, and ability to validate to observed data so that model configuration can be refined. For example, little data is generally available to describe sediment oxygen demand (SOD) in most streams, although this process is a key component in prediction of in-stream water quality. QUAL2E allows designation of a zero-order SOD term that can be refined through the validation process.

To configure the hydraulic characteristics of the streams for the model, EPA reviewed available physical data and literature values for parameterization of hydraulic equations utilized by QUAL2E. To configure the physical attributes of the streams, EPA estimated stream cross-sections by using one of these methods: 1) observed data (e.g., USGS stream gages) for the study site, 2) data from a neighboring stream with similar hydraulic characteristics, or 3) empirical methods. EPA estimated longitudinal profiles from digital elevation model (DEM) data. EPA refined the hydraulic model configuration by comparing model-predicted flows to observed data.

For configuration of the steady-state model of each study site, QUAL2E requires the assumption of constant flows and water quality for each model input including all point sources (CAAP facility), upstream flow, and inflow from tributaries or groundwater. For CAAP facility inflow, EPA determined flow magnitude and water quality from average observed conditions reported in the detailed survey. EPA assessed critical conditions in the stream by adjusting the model conditions to particular seasons or periods when stream impacts are of maximum concern (e.g., summer low flow period or period of maximum feeding). Specifically, EPA derived critical low (7Q10) estimates for months of high facility production levels and used these flows and production levels to drive the QUAL2E simulations. For background flows and water quality (upstream, tributary, and groundwater), EPA estimated values from observed data. When data was limited to describe background conditions, EPA collected data from similar neighboring streams. EPA carefully selected study sites with plentiful stream data to reduce the assumptions required to address such data gaps.

EPA configured water quality processes utilized by QUAL2E by using literature values. Such processes included mass transport (including first-order decay and settling), sediment oxygen demand (user-specified rate), algal growth as a function of temperature (via solar radiation), and algal, nitrogen, phosphorus, and dissolved oxygen interactions.

It is important to stress that the inputs for the case studies were synthesized from several data sources and the case studies themselves should not be considered realistic representations of specific regulated facilities. For example, EPA used water quality data from not only a single local sampling station or stream, but also considered data from similar streams in the watershed to develop more robust estimates of background conditions of the receiving stream at the point of CAAP discharge. EPA also in some cases used flow data from nearby watersheds and used watershed size to extrapolate flow data on the subject stream when monitoring data was not available (e.g., the data was not recent, flow data was not recorded at the gage). Rather, the water quality modeling case studies were used to develop a relationship between the key factors driving water quality response (percent TSS load reduction, baseline TSS effluent concentration, and dilution ratio) and simulated water quality response. The simulated water quality response for any given case study was then assumed to be valid for all facilities in the scope of EPA's final regulation with similar values for percent TSS load reduction, baseline TSS concentration, and dilution ratio (i.e., in the same "extrapolation category").

The following briefly summarizes basic facility and geographic information about the case studies EPA evaluated.

Case Study 1 ("LHL")

A case study to represent the "LHL" extrapolation category was developed using a facility located in the Blue Ridge Ecoregion (Central and Eastern Forested Uplands Nutrient Ecoregion) in the southeastern United States. Consistent with the definition of this extrapolation category (see earlier discussion), this facility has a "Low" regulatory percent TSS load reduction, a "High" baseline TSS concentration, and a "Low" dilution ratio. See Table 8-3 for specific values for this case study.

This government-owned facility uses a flow-through system to produce over 100,000 pounds of trout each year. The watershed encompasses over 2,000 square miles[13]. Primary land uses for this watershed include forestry and grazing[14]. Average temperature for this region is approximately 60 °F and average annual precipitation is approximately 50 inches[15]. A number of other detailed questionnaire facilities are located in the same general area.

Case Study #2 ("HLH")

A case study to represent the "HLH" extrapolation category was developed using a facility located in the Pacific Northwest. Consistent with the definition of the HLH extrapolation category, this facility has a "High" regulatory percent TSS load reduction, a "Low" baseline TSS concentration, and a "High" dilution ratio. See Table 8-3 for specific values. The selected facility is a government-owned salmon facility that is located in Coast Range Ecoregion (Western Forested Mountains Nutrient Ecoregion) of the United States. This facility produces just under 100,000 pounds of salmon annually. The watershed encompasses just over 670 square miles[16]. Average annual temperature is 51° F, and the mean annual precipitation is approximately 67 inches[17]. A number of other detailed questionnaire facilities are located in the same general area.

Case Study #3 ("LHH")

A case study to represent the "LHH" extrapolation category was developed using a facility located in the upper Midwest. Consistent with the definition of the LHH extrapolation category, this facility has a "Low" regulatory percent TSS load reduction, a "High" baseline TSS concentration, and a "High" dilution ratio. See Table 8-3 for specific values.

The selected facility is a government-owned trout facility that is located in the Northern Lakes and Forests Ecoregion (Nutrient Poor Largely Glaciated Upper Midwest and Northeast Nutrient Ecoregion) of the United States. The facility reports an annual production of over 200,000 pounds of trout. The watershed, which is approximately 1,600 square miles[18], has forestry as its primary land use,

---

[13] Environmental Statistics Group (ESG) provides several sources of watershed size. Available online at *http://www.esg.montana.edu*.

[14] Conservative Technology Information Center, Purdue University.

[15] Climatic data was obtained from NOAA. Since it was not available for the exact facility location, data from nearby were used to approximate conditions at the facility.

[16] Environmental Statistics Group (ESG) provides several sources of watershed size. Available online at *http://www.esg.montana.edu*.

[17] Climatic data was obtained from NOAA.

[18] Environmental Statistics Group (ESG) provides several sources of watershed size. Available online at *http://www.esg.montana.edu*.

with cropland and grazing as secondary uses[19]. The annual high temperature in this area is 80° F, with an average low temperature of 10° F, and average annual precipitation of 34 inches[20]. A number of other detailed questionnaire facilities are located in the same general area.

Case Study #4 ("HHL")

A case study to represent the "HHL" extrapolation category was developed using a facility in California. Consistent with the definition of the HLL extrapolation category, this facility has a "High" regulatory percent TSS load reduction, a "High" baseline TSS concentration, and a "Low" dilution ratio. See Table 8-3 for specific values.

The selected facility is a government-owned trout facility that is located in the Southern and Central California Chaparral and Oak Woodlands Ecoregion (Xeric West Nutrient Ecoregion) in the United States. The facility produces over 400,000 pounds of trout annually. The watershed is over 800 square miles[21]. The mean annual temperature is approximately 61° F, with mean annual rainfall of approximately 33 inches[22]. A number of other detailed questionnaire facilities are located in the same general area.

Estimating Benefits from Extrapolation Categories Not Modeled as Case Studies

EPA explored estimating benefits from the remaining extrapolation categories not already modeled with QUAL2E. As stated before, HLL was not considered because there are no facilities in this extrapolation category. Of the remaining categories (HHH, LLL, and LLH), EPA chose to estimate benefits from the HHH category because it had the highest percent TSS load reduction of the three categories and water quality improvements for facilities in the LLL and LLH categories were expected to be smaller than improvements from facilities in the HHH category. EPA first estimated benefits of the HHH category by using the QUAL2E model already developed for Case Study #2 (HLH). To accomplish this, EPA chose one representative facility from the HHH category (the facility from the nine HHH facilities whose dilution ratio is closest to the dilution ratio for Case Study #2) and adjusted the facility flow to match the flow of the receiving water in the Pacific Northwest. The effluent concentrations were adjusted accordingly). EPA then applied this facility effluent data to the model for Case Study #2. To test the sensitivity of using a different Case Study model to simulate water quality improvements from the HHH extrapolation category, EPA also used the model for Case Study #3. Larger water quality improvements were observed for the adjusted Case Study #2, in comparison to the simulated water

---

[19] Conservative Technology Information Center, Purdue University.

[20] Climatic data from the county level was used since data were not available for the exact location of the facility. Data obtained from NOAA was reported incorrectly, so EPA obtained corrected data from the county.

[21] Environmental Statistics Group (ESG) provides several sources of watershed size. Available online at *http://www.esg.montana.edu*.

[22] Since climate data were not available at the exact location of the facility, data from the nearest NOAA monitoring station were used.

quality improvements for adjusted Case Study #3. Therefore, EPA carried out “HHH” benefits monetization on the results for adjusted Case Study #3 to avoid overestimating benefits of the CAAP rule.

8.2.4.3 Model Results

For each of the case studies described above, including the HHH simulation, QUAL2E was used to generate simulated concentrations for selected water quality parameters over a 30 km distance downstream of each facility under both baseline and post-regulatory loading scenarios. QUAL2E output for DO, BOD, TSS, NO_3, and PO_4 are used to estimate a “water quality index” (WQI6) value, which in turn is used to estimate monetized benefits of improvements to water quality. The specific form of the function relating these water quality parameters to WQI6 is described in Section 8.2.4 of this Chapter.

Figure 8-1 displays example QUAL2E output for the BASELINE scenario at the QUAL2E simulation for Case Study #3, as adjusted to represent the “HHH” extrapolation category (documentation of all QUAL2E runs can be found in the Record for this rulemaking (Hochheimer et al., 2004 a-d)). Increases in pollutant concentrations can be seen a short distance downstream of the facility, located at river kilometer (RK) 0.5. Simulated improvements in water quality following regulatory loading reductions can be seen in Figure 8-2. Peak pollutant concentrations are lower following the regulation, resulting in a small increase in the value of WQI6 (Figure 8-3). The monetized benefit of the upward shift in the value of WQI6, best seen on Figure 8-3, is calculated as described in the following section.

EPA performed limited calibration on the case study models in the form of adjustments to input parameters, which were necessary to achieve reasonable values for the results. Because EPA was primarily interested in monetizing the benefits associated with regulatory changes, analysis of the relative differences in stream water quality based on changes to facility loads before and after regulation was most important, and EPA sought to calibrate the model so it could generate reasonable changes in water quality (rather than to calibrate the model to achieve accurate, absolute values for the water quality parameters). Therefore, EPA focused its calibration to ensure that the model output values were within normally expected ranges of values for the water quality parameters of interest. In the calibration, EPA adjusted model inputs that affect processes in the stream or contributing watersheds including the BOD_5 coefficient and coefficients for nitrogen, phosphorus and algae, such as oxygen-nitrogen hydrolysis and ammonia oxidation, which were important to ensure that the model represents streams similar to those located adjacent to the case study facilities.

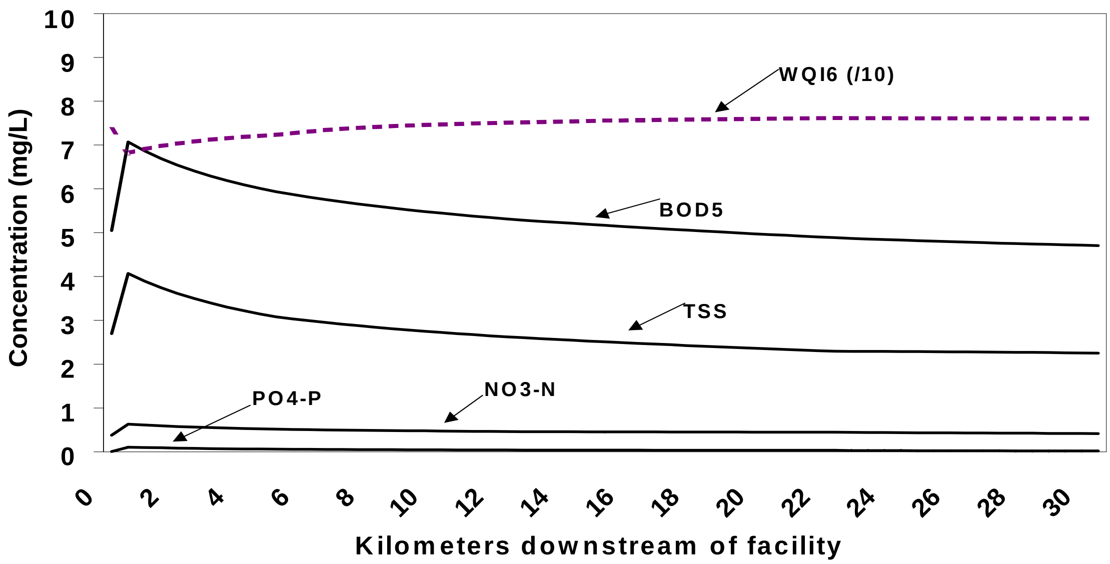

Figure 8-1. Sample QUAL2E output for ***baseline*** discharges in a 30 km reach downstream of a case study facility. The facility is located at river kilometer 0.5. Simulated BOD5, TSS, NO3-N, and PO4-P are shown by solid lines; aggregate water quality index (WQI6) - a function of the simulated parameters - is shown by the broken line. WQI6 divided by 10 to enable display on the same graph.

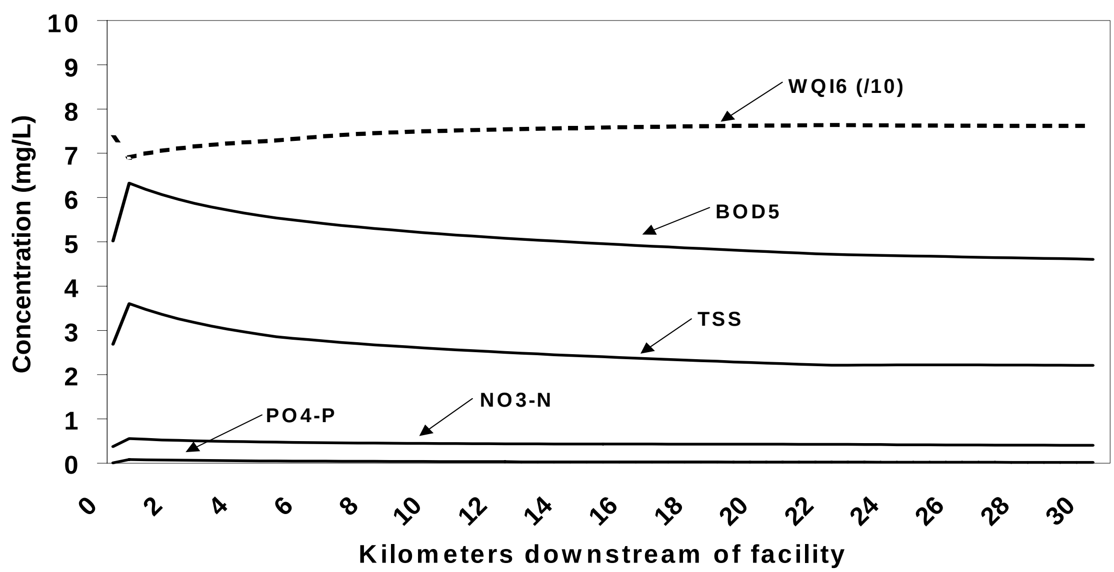

Figure 8-2. Sample QUAL2E output for ***post-regulatory*** discharges in the same reach and facility as shown in Figure 1. As in Figure 1, facility is at RK 0.5. See caption for Figure 1 and text for further discussion.

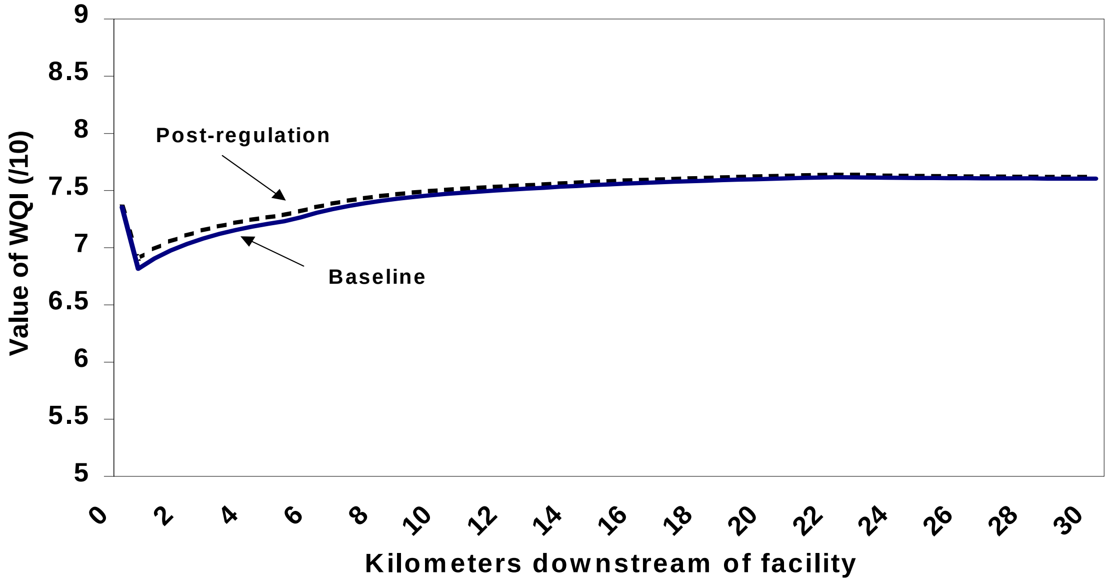

Figure 8-3. Comparison of baseline and post-regulatory WQI6 values from sample QUAL2E output presented in Figures 1 and 2. As in Figures 1 and 2, facility is located at RK 0.5. Upward shift in WQI6 indicates improved water quality. Monetized benefits at each facility are based on the cumulative improvement in water quality along the length of the 30 km simulated reach. See text for further explanation.

The following table summarizes QUAL2E model run characteristics and results:

Table 8-3
Summary of QUAL2E run results.

(A) Name/description	(B) % TSS load reduction	(C) Baseline TSS effluent concentration (mg/L)	(D) Dilution ratio	(E) Simulated change in water quality* (reach-average ΔWQI6)
Case study 1 (“LHL”) - facility in Blue Ridge ecoregion	1.2	10.01	0.17	0.0049
Case study 2 (“HLH”) - facility in Coast Range ecoregion	21.3	0.63	0.52	0.0385
Case study 3 (“LHH”) - facility in Northern Lakes and Forest ecoregion	3	3.63	0.28	0.0109
Case study 4 (“HHL”) - facility in Southern and Central CA Chaparral and Oak Woodlands ecoregion	51.6	1.5	0.18	0.2642
Case study 3, modified to represent “HHH” extrapolation category	21.9	13.1	0.37	0.3325

*Values in Column (E) from results reported in Miller, 2004.

8.2.5 Economic Valuation

8.2.5.1 Economic Valuation Approach

The process for assigning a dollar value to changes in water quality for each sample case study affected by the CAAP rule involves the following steps: (1) calculate changes in aggregate water quality index (WQI) values, based on predicted changes in water quality parameter concentrations, and (2) estimation of household willingness to pay (WTP) for the change in WQI, and (3) summation of benefits based on in-State and out-of-State populations of households.

In the first step, simulated water quality parameter changes for each case study and the HHH simulation are translated into a composite water quality index (WQI) value. The original WQI, from which the WQI used for CAAP rule was derived, included nine water quality parameters: five-day biochemical oxygen demand (BOD_5), percent dissolved oxygen saturation (% DOsat), fecal coliform bacteria (FEC), total solids (TS), nitrate (NO_3), phosphate (PO_4), temperature, turbidity, and pH. The concentrations of each water quality parameter are mapped onto a corresponding index number between 0 and 100 (zero equating with poor water quality) using functional relationship curves (McClelland, 1974). McClelland derived the functional relationships by averaging the judgments from 142 water quality experts. A composite WQI is estimated using the parameter specific weights and the function below; weights are again, based on the summary judgments of the expert panel.

$$\text{Composite WQI} = \prod_{i}^{I} X_i^{\alpha_i}\ ,\quad \sum_i \alpha_i = 1$$

where,

I = number of water quality parameters in the composite index,
X = index value for individual water quality parameter (0 to 100), and
α = parameter-specific weight.

For previous rulemakings, load reduction data, water quality data, and/or modeling capability did not extend to all nine parameters, so a modified WQI formulation had been developed for four of the parameters (WQI-4). The parameters were dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), and fecal coliform (FC). EPA applied this version of the WQI for the proposed rule. Because we do not expect loadings for FC to be discharged from CAAP facilities, we assumed that background levels of this parameter remain unchanged. EPA adopted a six-parameter WQI (WQI-6) for the final CAAP rule based on TSS, BOD, DO, FC, plus nitrate (NO_3) and phosphate (PO_4). The new index more completely reflects the type of water quality changes that will result from loading reductions for TSS, total nitrogen (TN), total phosphorus (TP), and BOD. Final rule benefits presented here were calculated on the basis of WQI-6. In the original index, McClelland (1974) used turbidity in her assessment rather than TSS. To incorporate TSS in the analysis for the final CAAP rule, a regression equation is therefore used to convert the original functional relationship curve of water quality against turbidity into a curve of water quality against TSS. The weight on each parameter was also recalculated so that the sum of weights equals one, thereby insuring that the composite index continued on a 0-100 basis even though it had fewer components. For the benefits analysis for the final rule, WQI-6 values are estimated before (i.e., baseline) and after implementation of final CAAP rule requirements for each half kilometer increment of the total 30 kilometer stream reach distance modeled for each case study and the HHH simulation.

In the second step, household willingness to pay (WTP) values are estimated for changes in WQI-6. Economic research indicates that the public is willing to pay for improvements in water quality and several methods such as stated preference surveys have been developed to translate changes in water quality to monetized values. At proposal, EPA based the water quality benefits monetization on household WTP values for discrete changes in recreational use classifications (e.g., boatable to fishable, fishable to swimmable water quality) as derived from a stated-preference survey conducted by Carson and Mitchell (1993). EPA divided the willingness-to-pay (WTP) values for changes in recreational water "use classes" by the number of WQI units associated with each use class. For example, Carson and Mitchell's survey informed the respondent that boatable, fishable, and swimmable waters are mapped onto respective ranges of WQI values of 25 to 50, 50 to 70, and greater than 70. EPA was therefore able to assign incremental WTP values for each unit change in the aggregate WQI.

For the final CAAP rule, EPA adopts an alternative approach, also based on Carson and Mitchell's work. In addition to describing their results in the form of WTP for discrete changes in recreational use classifications, the authors also estimated household WTP as a function of the WQI representing all of the nations waters and household income.

Carson and Mitchell (1993) derived an equation to assess the value of water quality along the continuous WQI scale using the responses to their national survey. Assuming that the proportion of families engaging in water-based recreation and the proportion of respondents who feel a national goal of protecting nature and controlling pollution is very important are the same as when the Carson and Mitchell survey was completed, the incremental value associated with increasing WQI from WQI_0 to WQI_1 can be calculated as:

$$WTP_{TOT} = \exp[0.8341 + 0.819\log(\tfrac{WQI_1}{10}) + 0.959\log(\tfrac{Y}{1000}) - \exp[0.8341 + 0.819\log(\tfrac{WQI_0}{10}) + 0.959\log(\tfrac{Y}{1000})]$$

where

WTP_{TOT} = a household's willingness-to-pay for increasing water quality (1983 dollars)
Y = household income (sample average = $35,366 in 1983 dollars)
WQI_1 = Composite water quality index under regulatory scenario
WQI_0 = Composite water quality index under baseline

In this case, Y was selected to correspond to an estimated mean household income of $35,366 in 2003 expressed as 1983 dollars (note: 2003 mean household income projected using US Census 2001 mean household income and percent increase in Bureau of Economic Analysis real per capita disposable income from 2001 to 2003; 2003 income adjusted to 1983 dollars using CPI-U-RS). The resulting value estimates were inflated to 2003 dollars using the growth rate in the consumer price index (CPI) of 1.8574 since 1983 (U.S. Department of Labor, Bureau of Labor Statistics, www.bls.gov/cpi). WTP_{TOT} values are estimated for each change in WQI for each half kilometer increment of each 30 kilometer in the models. The sum of values for the modeled reach is equal to the monetized value for a single household.

In the third step, EPA estimates benefits for the total population of households. Benefits are calculated state-by-state and are broken down into local and non-local benefits. Carson and Mitchell (1993) found that respondents were willing to pay more for water quality improvements within their own state, and estimated that 2/3 of the total willingness-to-pay applied to in-State water quality changes. Non-local benefits correspond to the amount a population is willing to pay for water quality improvements outside of their own state, and were estimated as 1/3 of the total willingness-to-pay (i.e., it assumes households will allocate two-thirds of their willingness to pay to improvements in-State waters). For details about final benefit calculations, see Miller (2004).

8.2.5.2 Uncertainties and Other Considerations Regarding Benefits Valuation

As noted above, EPA relies on a willingness to pay function derived by Carson and Mitchell to value changes in the water quality index for reaches affected by this rule. This function has the ability to capture benefits of marginal changes in water quality. Based on this approach, EPA is able to assess the value of improvements in water quality along the continuous 0 to 100 point scale, and values are less sensitive to the baseline use of the water body (relative to methods used for the proposed rule). The calculation of benefits is completed separately for each State and takes into account differences in willingness to pay for local and non-local water quality improvements. Note that the WTP function assumes decreasing marginal benefits with respect to water quality index values; this is consistent with consumer demand theory and implies that willingness to pay for incremental changes in water quality decreases as index values increase. There are a number of other issues associated with the transfer of values from the Carson and Mitchell survey results that affect benefit estimates for this final rule, and these issues are discussed below.

Economic benefits of the this rule can be broadly defined according to categories of goods and services provided by improved water quality: use and nonuse benefits. The first category includes benefits that pertain to the use (direct or indirect) of the affected resources (recreational fishing). The direct use benefits can be further categorized according to whether or not affected goods and services are traded in the market (commercial fish harvests). For this rule, EPA has not identified any goods that are traded. The non-traded or non-market "use" benefits implicitly assessed in this final rule include recreational activities. Nonuse benefits occur when environmental improvements affect a person's value for a natural resource that is independent of that person's present use of the resource. Nonuse values derive from people's desire to bequeath resources to future generations, vicarious consumption through others, a sense of stewardship or responsibility for preserving ecological resources, and the simple knowledge that a resource exists in an improved state.

When estimating nonuse benefits, it is not possible to directly observe people using the good or resource, therefore, more traditional revealed preferences economic methods such as travel costs are not applicable to the derivation of nonuse values. Instead, analysts survey people and directly ask them to state their preferences or willingness to pay for an environmental improvement (e.g., what are you willing to pay to improve water quality from boatable to swimmable). Statistical models are used to compile these survey responses and derive nonuse values for the resource improvements specified in the survey questions[23]. The values estimated from stated preference surveys may capture both use and nonuse values depending on how the survey is implemented.

The Carson and Mitchell stated preference study is a case were both use and nonuse benefits were estimated (i.e., Total willingness to pay). The willingness to pay values developed in their national survey are the basis for the benefits transfer, which produced the total benefit values sited in this report. Carson and Mitchell asked respondents how they would divide their total willingness to pay values for improved water quality between their home state and the rest of the nation. The fact that Carson and Mitchell were asking people to value significant changes in water quality across the nation can present a source of error in the estimation of the benefits for today's rule. This is due to the imprecise fit between the scenario presented in their survey questions and the more narrow scope, both in terms of the number of water bodies and the size of the water quality change, of the CAAP rule. The direction of the impact produced by this difference between the survey and policy scenarios on our estimated use and nonuse benefits, for today's rule, is unclear.

EPA notes that an additional source of indeterminate error is imposed by the benefits transfer framework stemming from the assumption that willingness to pay for the same level of water quality

---

[23]In 1993, the National Oceanic and Atmospheric Administration (NOAA) convened a panel of economists to evaluate a form of stated preference methods (*contingent valuation* (CV)) and to devise a set of "best practices" for designing and implementing CV surveys. The NOAA recommendations are in the Federal Register (1994). EPA has subsequently published "considerations in evaluating CV studies" and discusses other stated preference methods in the agency's *Guidelines for Preparing Economic Analyses* (2000). OMB's most recent draft of "best practices" for conducting regulatory analysis, recognizes nonuse values and provides guarded acceptance of stated preference methods by listing "principles that should be considered" when evaluating the quality of such a study (Draft OMB Circular A-4, 9/17/03).

improvements, from the same baseline level of quality, are constant across all water-bodies. This restriction implies that people have the same value for a similar improvement in water quality in water bodies that may differ in terms of geographic location, surrounding land use, and recreational use pressure.

Two additional sources of error can be identified that would tend to produce an underestimate of use and nonuse benefits for the rule. Values returned by stated preference studies are sensitive to the language used to inform respondents about the baseline conditions and the changes in resource produced by the policy being evaluated. The nonuse component of Carson and Mitchell's reported total willingness to pay may be under estimated because of the use of recreational activity based titles for differing water quality categories i.e. boatable, fishable, swimmable. These designations are likely to produce cognitive links in respondent's minds to benefits associated with recreational uses, and down play the role of nonuse benefits. Recreational "tags" may have lead to an incomplete recognition of nonuse benefits in Carson and Mitchell's total willingness to pay valuation and therefore under-estimation of benefits for the rule.

An issue in applying the results of the Carson and Mitchell survey in the context of the water quality index is the treatment of water quality changes occurring below the boatable range and above the swimmable range. There are concerns that the survey's description of non-boatable conditions (i.e., index values less than 25) was exaggerated (i.e., unsafe for boating and swimming and unfishable), which implies that willingness-to-pay estimates for improving water to boatable conditions (i.e., index increases above 25) may be biased upwards. The survey did not ask respondents how much they would be willing to pay for improved water quality above the swimmable level.[24] These issues increase the uncertainty associated with valuing water quality changes outside the boatable to swimmable range (i.e., for water quality index values below 26 or above 70). In recognition of this uncertainty, EPA determined that some percentage of the benefits are derived from changes in water quality outside the boatable to swimmable range (i.e., less than 25 or greater than 70).

In addition to the valuation function, there is also uncertainty associated with the water quality index. The water quality index used in monetization for the final rule relies on judgements of water quality experts from the 1970s when they were asked to assign index values to different levels of individual pollutant parameters. There is some evidence suggesting that updating index values may be appropriate. This can be illustrated through a discussion of the nutrient values in the index in comparison to recent work on nutrient criteria development. EPA's recently recommended section 304(a) ecoregional water quality criteria for nutrients to define reference conditions for reducing and preventing cultural eutrophication. Index values for nitrate nitrogen and phosphate phosphorus nutrient criteria representing 304(a) 50th percentile (i.e., median) reference conditions of 'least impacted' streams are relatively high as indicated in Table 8-4. Given that fishable water quality is designated as starting at an index value of 50, swimmable at 70, and water quality suitable for drinking without treatment at 95, these results suggest that the index is overestimating baseline water quality index values associated with nutrients (e.g., 50% reference conditions for healthy aquatic life are an average of 92 and 93 index units for PO_4 and NO_3 respectively, well above an assumed index value of 50 for fishable water). Overestimation of baseline index values potentially translates into underestimation of benefits given that marginal willingness to pay for incremental changes in water quality decreases as baseline water quality increases (i.e., demand decreases with quantity). This result may be offset to some extent by the possibility that modeled

[24] However, respondents were made aware of the potential for water quality to improve beyond swimmable in the ladder (e.g., drinkable).

changes in nutrient concentrations will be translated into small changes in index value as the nonlinear index curve becomes more convex. In general, these results suggest that the water quality index may not reflect current evidence about the contribution of nutrients to water quality, as represented by recent 304(a) recommended ecoregional water quality criteria for nutrients. While this discussion has focused on nutrients, similar issues may be applicable to index values for TSS and BOD.

Table 8-4
Index Values for Nutrient Criteria

50% Reference Conditions[1]		Estimated 50% Criteria[2]		Parameter Index Values[3]	
Total P	**Total N**	**PO4-P**	**NO3-N**	**PO4-P**	**NO3-N**
0.07 mg/l	1.1 mg/l	0.053 mg/l	0.97 mg/l	92	93

1. Average of section 304(a) ecoregion water quality criteria representing 50th percentile reference conditions of 'least impacted' streams across 14 ecoregions.
2. Estimated criteria derived from 50% reference conditions and the following relationships [PO4-P] = 0.75*[TP], [NO3-N] = 0.9*[TN]
3. Index values derived by inserting 'Estimated 50% Criteria into regression functions fitted to index curves for PO4-P and NO3-N from McClelland (1974) (i.e., index curves 'map' concentrations into index values).

8.2.6a Estimated National Water Quality Benefits—Options A and B

EPA estimates the national water quality benefits of Option A to be $84,000 or, for Option B, $94,000 to $118,000. Table 8-5a summarizes data used to develop the national benefit estimate for Option B. As described in Section 8.2.2, each of the 24 in-scope, detailed questionnaire facilities with non-zero load reductions were assigned to an appropriate extrapolation category where data allowed (Column (C) of Table 8-5a). Each facility was further assigned the value of change in WQI6 (d(WQI6)) corresponding to the appropriate extrapolation category (Column (F) in Table 8-5a; see also Table 8-3). As noted earlier in this Chapter, receiving water flow data, and thus a complete extrapolation categorization, could not be done for 9 of the 24 facilities in Table 8-5a.

As described in Section 8.2.4.1, monetized benefits for d(WQI6) are calculated on a state-by-state basis. Column (B) of Table 8-5a indicates the EPA region in which each facility is located (the State in which the facility is located was used in monetizing benefits, but EPA region, rather than State, is provided in Column (B) as a means of aggregation to protect potential confidential business information (CBI)). Thus, the value in Column (G) indicate the monetized benefit calculated for the appropriate d(WQI6), taking into consideration the State in which the facility is located. Column (H) represents the benefit for all facilities in the national, regulated population, represented by the detailed questionnaire facility (i.e., the sample weight for the detailed questionnaire facility, Column (D), multiplied by the benefit value for the detailed questionnaire facility in Column (G)).

Two additional steps were taken to estimate the water quality benefits. First, EPA assumes that it is more appropriate to apply the Carson-Mitchell valuation method to larger-sized streams, where recreation is more probable, rather than smaller-sized streams where recreation is less probable. Accordingly, EPA took the step of omitting from the monetized benefit analysis certain facilities located on smaller-sized streams. To do this, for all facilities for which receiving water flow data could be found, EPA determined whether the stream was part of a national subset of larger streams (referred to as

Table 8-5a
National Water Quality Benefit Estimate for Option B

(A) No.	(B) EPA Region	(C) Extrap. Category	(D) Sample Weight	(E) RF3Lite Flag	(F) d(WQI6)	(G) Estimated Benefit	(H) Extrap. Benefit (L)	(I) Extrap. Benefit (H)
1		HHH	5.35	0	0.3325			
2		HHH	3.73	1	0.3325	$ 16,741	$ 62,505	$ 62,505
3		HH_	1.31	n.d.	n.d.			$ 16,423
4		HHL	3.87	0	0.2642			
5		HHL	3.92	1	0.2642	$ 5,537	$ 21,683	$ 21,683
6		HLH	3.73	1	0.0385	$ 1,919	$ 7,165	$ 7,165
7		HL_	1.53	n.d.	n.d.			$ 4,477
8		LHH	3.67	0	0.0109			
9		LHH	3.89	0	0.0109			
10		LHH	5.22	1	0.0109	$ 237	$ 1,238	$ 1,238
11		LH_	4.66	n.d.	n.d.			$ 1,440
12		LH_	4.10	n.d.	n.d.			$ 427
13		LHH	3.70	1	0.0109	$ 327	$ 1,211	$ 1,211
14		LH_	3.49	n.d.	n.d.			$ 1,266
15		LHL	1.78	0	0.0049			
16		LH_	3.68	n.d.	n.d.			$ 298
17		LH_	1.39	n.d.	n.d.			$ 140
18		LLH	3.73	0	n.d.			
19		LLH	3.73	1	n.d.			
20		LL_	1.37	n.d.	n.d.			
21		LL_	3.46	n.d.	n.d.			
22		LLH	3.68	1	n.d.			
23		LLL	3.68	1	n.d.			
24		LLL	3.68	1	n.d.			
						Option B TOTAL	$ 93,803	$ 118,274

the RF3 Lite network of streams[25]. A value of 1 in Column (E) indicates that a facility is part of the RF3 Lite network. EPA did not estimate any benefits for facilities determined not to be part of the RF3 Lite network (i.e., with a value of 0 in Column (E).) Thus, if the value in Column (E) is 0, then there are no benefit values in Columns (G), (H), or (I).

Second, for facilities where receiving water flow data (and thus dilution ratio) could not be determined (i.e., facilities with "n.d." in Column (E)), EPA pursued two alternative assumptions. For a lower bound estimate of benefits, EPA assigned a benefit value of 0 to all facilities for which receiving water flow data could not be determined. The sum of the values in Column (H) represents this lower-bound estimate ($94K). For an upper-bound estimate of benefits, EPA essentially assumed an "average" dilution ratio value for facilities with no receiving water data and developed a benefit estimate based on this assumption. Column (I) contains the estimated benefits for these facilities, and the sum of the values in Column (I) represents this upper-bound estimate ($118K). Again, the approach for estimating the national benefit for Option A was done in the same manner as that for Option B discussed above. For more detailed descriptions of the method described in this section, see McGuire, 2004a.

8.2.6b Estimated National Water Quality Benefits—Final Option

EPA estimates the national water quality benefits of the final Option to range from $66,214 - $98,616 (Table 8-5b). Table 8-5b indicates benefits, by extrapolation category. In general, the benefits estimate was developed using the same steps described in section 8.2.6a although the Table 8-5b is less detailed than Table 8-5a and presents only a summary of the results of these steps. The benefit estimate for the final Option also reflects minor updates to the final list of in-scope facilities and sample weights that were not reflected in the estimate for Options A and B. Please see McGuire (2004) for more detail on the calculations for the final Option.

Table 8-5b
National Water Quality Benefit Estimate for the Final Option

Extrapolation category	Total national benefit for category ($2003)
LLL-LLH	not estimated
LHL-LHH	$2,126 - $5,330
HLL-HLH	$6,591 - $12,031
HHL-HHH	$57,497 - $81,255
TOTAL BENEFITS, FINAL OPTION	$66,214 - $98-616

[25]The EPA Reach Files (RFs) are a series of hydrologic databases that contain information on the U.S. surface waters. The RF3 Lite subset of surface waters contains streams that are greater than 10 miles in length (and also small streams needed to connect streams greater than 10 miles in length into a complete network). There are approximately three times as many miles of streams in the overall network as compared with the RF3 Lite subset (USEPA, 2003).

8.2.7 Sources of Uncertainty

In addition to the sources of uncertainty associated with the monetization method, described in Section 8.2.4.2, there are a number of other sources that contribute uncertainty in the above estimate of water quality benefits of the regulation. Several important sources include the following:

- Uncertainty in choice of factors that drive water quality. EPA has assumed that facilities with similar regulatory percent TSS load reductions, baseline TSS concentrations, and dilution ratios (see Section 8.2.2) will experience similar changes in water quality. On the basis of this assumption, EPA assumes that all detailed questionnaire facilities in the same "extrapolation categories" may be grouped together and a single QUAL2E case study model for a facility within the category will be representative, in terms of change in WQI6, of all facilities in the extrapolation category. Errors in this assumption—WQI6 response is unrelated to these three factors—could lead to incorrectly attributing large or small water quality responses to facilities. Errors in this assumption could lead to underestimates or overestimates of benefits. As noted earlier, EPA informally evaluated the relationship between percent TSS load reduction, baseline TSS concentration, dilution ratio, and simulated water quality response. EPA performed multiple regression analyses between the three explanatory factors and change in WQI6 using four different model specifications (linear without constant, linear with constant, semilog, and log-log). The three explanatory factors explained from 73% to 99% of the variation in d(WQI6), depending on model specification. See McGuire (2004c). The regression results support the assumption that these three factors are important determinants of water quality response.

- Coarseness of extrapolation categorization. The coarseness of categorization for each factor (only two possible values, "Low" and "High," for each of the three factors) may introduce uncertainty in the benefits estimate. A larger number of extrapolation categories for each factor, or alternatively a different approach (e.g., developing a relationship between QUAL2E-simulated d(WQI) and key explanatory factors such as percent TSS load reduction, baseline TSS effluent concentration, and dilution ratio), could potentially reduce, and better enable a characterization of, this source of uncertainty.

- Uncertainty in case study specification. EPA configured each case study using EPA estimates of baseline pollutant loads, regulatory load reductions, receiving water flow and quality, and facility effluent flow. Each of these estimates is subject to some uncertainty. For example, the accuracy of reported feed use, facility flow rates, annual production, and estimates of feed conversion ratios could lead to underestimates or overestimates of both baseline and regulated load estimates. Uncertainty associated with data available to EPA for stream characteristics such as storm flows, water quality, or the physical attributes of the stream can change how the CAAP effluent will affect receiving water quality. These changes in stream characteristics should result in a systematic error (either up or down in terms of changes to water quality) that should not impact the relative differences associated with the regulated CAAP effluent. However, if the stream characteristics are too different than actual conditions (e.g., flows are much greater than modeled or background water quality masks any changes or influence by the facility) then the differences between baseline and regulated conditions may be masked.

  The results of running the QUAL2E simulations of the HHH extrapolation category with Case Studies # 2 and 3 show how changes in facility flow or effluent concentration will alter the results of the changes in water quality. For example, in the original Case Study

#2 model, BOD first decreases and remains relatively constant 30 km downstream as it begin to slightly recover. The results of the adjusted Case Study #3 show BOD increasing first and then decreasing going downstream. This example show how differences in facility and environmental conditions used for flow and effluent concentrations may result in differences in absolute values of baseline water quality for different QUAL2E simulations. Again, it is important to note that the simulated *change* in water quality is the variable of most interest in the benefits analysis.

- Uncertainty in model specification. QUAL2E, like other water quality models, simulates certain physical, chemical, and biological processes. However, in many cases specific parameters must be estimated when actual values are not available. For example, mean solar radiation values for a facility were based on an average of mean daily solar radiation values for different cities in the state where the facility is located. Rate coefficients for nitrogen transformations, such as nitrogen hydrolysis and nitrite oxidation, are based on a set of typical ranges. Modelers often choose the average value of a range when no other data is available. When no specific SOD monitoring data was available for the modeled streams, the average SOD rate for a sandy bottom river was used to represent the real stream being modeled.

- Uncertainty in survey weights. As described in section 8.2.2, EPA established survey weights based on facility type, predominant species, and predominant production system type. In applying these survey weights to develop a national benefit estimate from the detailed questionnaire facilities in a particular extrapolation category, EPA assumed that the facilities represented by the survey weights would experience similar benefits as the facilities in each extrapolation category. However, the facilities that are represented by the survey weights are not necessarily similar to the facilities in each extrapolation category with respect to important factors that drive water quality responses (e.g., percent load reduction resulting from the regulation; baseline pollutant concentration in effluent, and dilution ratio) and important factors that drive benefits (e.g., state populations). A better method of extrapolation would involve estimating the number of facilities in the total in-scope population that are similar to the detailed questionnaire facilities on the basis of key factors that drive water quality benefits. The use of the survey weights for extrapolating leads to additional uncertainty in EPA's national benefits estimate.

8.3 REFERENCES

Brown, L.C., and T.O. Barnwell, Jr. 1987. *The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual*. EPA 600-3-87-007. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, GA.

Carson, R.T., and R.C. Mitchell. 1993. The value of clean water: the public's willingness to pay for boatable, fishable, swimmable quality water. *Water Resources Research* 29: 2445-2454.

Hochheimer, J. 2004. *Site Selection for Water Quality Modeling*. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J., D. Mosso, and J. Harcum. 2004a. Final: Case Study 1 QUAL2E Model. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J., D. Mosso, and J. Harcum. 2004b. Final: Case Study 2 QUAL2E Model. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J., D. Mosso, and J. Harcum. 2004c. Final: Case Study 3 QUAL2E Model. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J., D. Mosso, and J. Harcum. 2004d. Final: Case Study 4 QUAL2E Model. Tetra Tech, Inc., Fairfax, VA.

McClelland, N.I. 1974. *Water Quality Index Application in the Kansas River Basin*. EPA 907-9-74-001. U.S. Environmental Protection Agency, Kansas City, MO.

McGuire, L. 2004a. *Benefits Estimate, Final Rule*. U.S. Environmental Protection Agency, Washington, DC.

McGuire, L. 2004b. *Flow Data for Water Quality Modeling*. U.S. Environmental Protection Agency, Washington, DC.

McGuire, L. 2004c. *Regression Model*. U.S. Environmental Protection Agency, Washington, DC.

Miller, C. 2004. *Valuation Spreadsheets*. U.S. Environmental Protection Agency, Washington, DC.

Tetra Tech, Inc. 2004. *Supporting Documentation for Extrapolation*. Tetra Tech, Inc., Fairfax, VA.

USEPA (U.S. Environmental Protection Agency). 2000. *Guidelines for Preparing Economic Analyses*. EPA 240-R-00-003. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002. *Detailed Questionnaire for the Aquatic Animal Production Industry*. OMB Control No. 2040-0240. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2003. *Estimation of National Economic Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations (CAFOs)*. EPA-821-R-03-009. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2004. *Development Document for the Final Effluent Limitations Guidelines and Standards for the Concentrated Aquatic Animal Production Point Source Category*. EPA 821-R-04-012. U.S. Environmental Protection Agency, Washington, DC.